that the older data (which were reduced by the present system of computation long before the inconsistencies among the various sets of the present observations were eliminated) are in close agreement with the present results.

PHYTOPATHOLOGY.—*Environmental influences in the pathology of Solanum tuberosum.*[1] W. A. ORTON, Bureau of Plant Industry.

The health and vigor of plants is largely dependent on their adaptation to their environment. Each species has its optimum requirements as to temperature, moisture, light and substratum, variations from which result in failure of the plant to reach a normal or maximum development and predispose it to disease.

Under certain environmental conditions, for example, the plant becomes more susceptible to the attacks of parasites, either because the germination and development of the parasite is favored or because the weakened host has lost its natural resistance. Another type of disease is not associated with any parasites, but comes from some perversion or loss of physiological functions, which seems also, in the last analysis, to be attributable to defects in the environment.

It is to be expected that the most favorable climate for any plant will be that of its nativity, to which it has become adapted in the course of its evolution. Certainly the students of crop plants should consider first the natural adaptations of their plant in the land of its origin, and next any modification that may have resulted from subsequent culture in other countries.

The native habitat of *Solanum tuberosum*, the progenitor of our potato, is believed to be in southern Chile, where it was found growing wild by the early explorers and where it still occurs. Darwin, in the *Voyage of the Beagle* describes his experiences on the Island of Chiloe, where "the wild potato grows . . . . in great abundance, on the sandy, shelly soil near the sea beach."

[1] Address of retiring President, Botanical Society of Washington, February 25, 1913.

De Condolle, after a critical study of the evidence, concludes that the potato is native in southern Chili and expresses doubt as to Peru and the other northern Andean countries, where it was in general cultivation by the natives at the time of the discovery and conquest by the Spaniards and where its present occurrence in a wild or semi-wild condition may be thru escape from the primitive Indian cultures.

That our potato may have come from a region where high altitudes give a temperate climate within the tropics is, however, not impossible, since other species of Solanum do occur thruout the Andean region and northward as far as Colorado, and may have given origin or contributed thru crossing to the potato which we cultivate today. There is great need for further taxonomic studies to throw light on this point. From the physiological standpoint, however, there can be no doubt that the potato originated in a region of low and uniform summer temperature, a fact of the greatest significance to agriculture in the United States, where different climatic conditions prevail.

It will be shown that in the Northern Hemisphere those regions are most successful in the cultivation of the potato where the temperatures during the growing period most nearly approach those of southern Chili, and that the climatic environment is the most important factor influencing the diseases of this crop.

The climate in the district where we believe the potato to be indigenous is marked by very uniformly cool summers and heavy winter rainfall. Valdivia has a mean annual temperature of 52.8°F. the maximum is 90°; and the minimum 30° (figs. 1 and 2); Puerto Montt and Ancud are similar. To the northward, as the climate becomes hotter and drier, the potato is more and more restricted to the higher elevations, where the climate is temperate and the summers cool and equable. The relative atmospheric humidity will be high in these cool regions. This is doubtless a more important point for the normal development of the potato than the absolute rainfall.

Of all countries where it has been introduced the potato perhaps yields best in Scotland, and here we find the summer nearly

as cool as in Chili, though the rainfall is less (figs. 1 and 2). Northern Germany is justly renowned for its potato harvests, which, in bushels per acre, are more than double those of the United States, and there also the growing period is long, cool and equable. The limiting factor is the rainfall, which is low, tho well distributed (Cf. Edinburg and Posen in figs. 1 and 2).

The July isotherm of 65°F. crosses North America not far from the northern border of the United States. Only in Aroostook County, Maine, and parts of northern New York have we develooped extensive potato culture north of this isotherm, which in

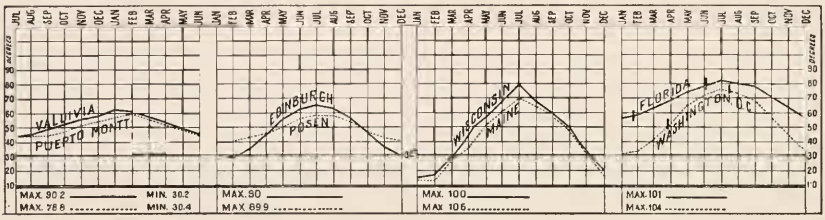

Fig. 1. Curves of mean monthly temperatures for Valdivia and Puerto Montt, in southern Chile, compared with Edinburgh, Scotland; Posen, Germany; Handcock, Wisconsin; Aroostock County, Maine; Federal Point, Florida, and Washington, D. C. Data from the first four were compiled from Hann's "Klimatographie;" the latter four from reports of the U. S. Weather Bureau.

Europe runs south of the principal potato districts of Great Britain and northern Germany. The isotherm of 70°F. (21°C.) for June, July and August nearly marks the southern boundary of successful main crop potato production in the United States. The climate of the greater part of the United States is therefore too hot for best results with this crop. As shown in figures 1 and 3, the production of potatoes in the South is a matter of early spring planting and summer harvesting, or of planting in late summer for autumn harvests. For the latter procedure a type of potato illustrated by the variety McCormick is well adapted in the region of Washington, D. C., a fact worthy of mention here for its significance in the problem of securing a heat resistant potato for southern districts. The summer heat of the United States is the limit-

ing factor in potato production. Only young plants can survive exposure to 90°F. for any extended priod, hence we find a tendency to plant late in the north in order that the time of tuber formation may come during the cooler weather of autumn.

It appears that most or all of our present varieties originated in northern districts, from parent stocks having low temperature requirements. To secure varieties capable of extending potato culture southward local breeding should be practised if stocks possessing the necessary physiological qualities can be found. Our great need is to discover a variety of *Solanum tuberosum*,

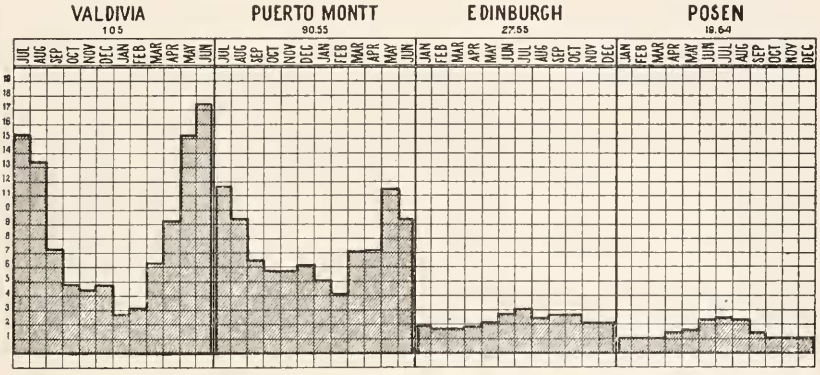

Fig. 2. Chart showing average monthly rainfall for points in southern Chile as compared with Europe.

or a species sufficiently related to hybridize with it, that is indigenous to a region of high temperature, and capable of transmitting to crosses with existing cultivated races a heat enduring quality derived thru better control of transpiration, or in other ways. It will be evident from a consideration of the south Chilean climate that the heat resistant factor cannot be found there. We must turn to more northern and warmer sections of South or Central America, a region that has been very inadequately explored to date, but where Mr. Wight of this Society is now engaged on this mission.

Turning now to the consideration of potato diseases, we shall find in the late blight, caused by the fungus *Phytophthora infestans*, an excellent illustration of the extent to which climatic environ-

ment influences disease. Late blight is limited by its requirements of abundant moisture and moderate temperature, hence it is most common in the Northeastern States, occasionally extending southward in early summer or autumn, never in midsummer. Hot or dry weather checks its spread. These well established facts strongly support the hypothesis that *Phytophthora infestans* is endemic in the native habitat of the potato. Our knowledge of the general principles of immunity in plants further suggests that there would be the place to seek strains of the host plant possessing a high resistance to this parasite.

In early blight, due to the fungus *Alternaria solani*, we find that higher temperatures than those best for the potato appear to promote infection. The range of greatest prevalence is well to the south of that for late blight.

Another instance of apparent geographical limitation of potato diseases is afforded by the wilts due to *Fusarium oxysporum* and *Verticillium albo-atrum* respectively. The Fusarium wilt is southern in its general range, being most prevalent in California, in the warmer irrigated valleys of the West and in the East Central States. Verticillium, on the other hand, occurs in the most northern districts from the Puget Sound to Maine. The two overlap in their distribution but have the general tendency stated.

Pathological conditions not due to parasites are even more conspicuously associated with attempts to grow the potato outside of its natural range. A heat and drought reaction common in the United States is that known as tipburn, where the leaves exposed to the hot sun and low relative humidity of midday curl and burn at the margins, indicating an excessive transpiration. This is seldom met with in Europe.

Premature ripening follows when potatoes bearing half-grown tubers are exposed to the midday heat of our Southern States. There is in addition to the tipburn a yellowing and early death of the foliage. Potatoes produced in these southern conditions lose their constitutional vigor and germinate later, with small weak sprouts and give a smaller yield than seed from northern sources. This constitutional defect is not cured by restoration to a northern environment.

There is another group of apparently physiological or inheritable potato diseases, of which "leaf roll" and "curly dwarf" are most important, which I bring into this discussion because they are probably deterioration phenomena connected in some way not yet fully understood with the effect of unfavorable environmental conditions.

The great losses that have been caused by these diseases both in Europe and America have caused much alarm and led to much investigation and discussion. The suggestion that our potato

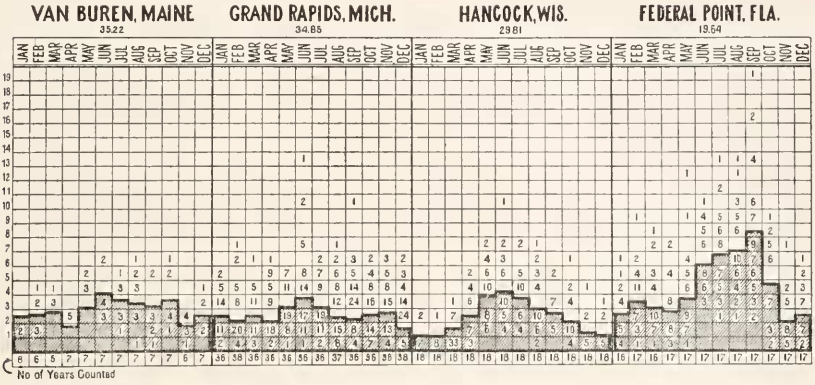

Fig. 3. Average monthly rainfall for four potato centers in the United States. Data from U. S. Weather Bureau. The heavy upper border of the shaded area shows the mean rainfall for the number of years indicated at the base of the column. The figures within the squares in the shaded area show the number of years within the period of record when the rainfall has been below the amount indicated. The corresponding figures in the white squares show the number of years during the period of record when the rainfall has exceeded the amount indicated.

varieties may suffer rapid deterioration thruout extensive districts and without discoverable cause is naturally provocative of uneasiness. While the nature and cause of "leaf roll" and related troubles is still largely a matter of speculation, the haze is partially cleared by the separation of this complex into at least five different troubles, three of which are attributable to known parasites.

As pointed out by the writer in December, 1911, in a paper before the American Phytopathological Society, the following diseases have been more or less confused by various observers:

1. Potato wilt due to *Fusarium oxysporum* (Schlecht.) Sm. & Sw., a disease widespread in the central and southern United States but not yet proved to exist in Europe.

2. Potato wilt due to *Verticillium albo-atrum*, a disease occurring in the northern United States, in Great Britain and northern Europe.

3. Potato rosette and other troubles caused by Rhizoctonia, especially prevalent in the western United States.

4. Leaf roll, an inheritable, probably non-parasitic disease prevalent in Europe and parts of America.

5. Curly dwarf, an inheritable, non-parasitic disease found both in Europe and America.

Leaf roll (Blattrollkrankheit) is a disease characterized by an upward rolling of the leaves, by a decreased yield of tubers and by transmission of the diseased condition thru tubers planted.

The rolling of the leaves is the most constant and conspicuous symptom of this disease. The leaflets curl or roll upward on their midrib, often assuming a nearly tubular shape, and giving the plant a staring appearance. This rolling is sometimes restricted to the upper leaves, while in other cases all or nearly all of the leaves on the plant exhibit it. This type of roll is distinct from the curly leaf condition but a very similar roll may be induced by other causes, such as wet soil, "black leg" and other diseases.

The color of the foliage changes with the advent of leaf roll, but these color symptoms vary greatly, from cases where the leaves assume an unhealthy, light green color to those marked by pronounced yellowish, reddish or purplish colors.

The time of onset is early as compared with Fusarium wilt. The effect on the plant is to check development. There is a lessening or cessation of growth. The duration of life of the plant, in some cases appears to be shortened by leaf roll, but in comparison with the rapid death of American potatoes attacked by Fusarium wilt the leaf roll is very slow in the action.

The endurance of the seed piece as a character of leaf roll is an interesting point frequently mentioned in the German literature, and is considered by Appel to be one of the symptoms of leaf roll. The effect of leaf roll on the tubers is strongly marked.

In general the yield is very much reduced. The diseased hills have numerous tubers very much smaller than normal so that the yield is only about half that of a healthy field. If one uses these potatoes again for seed, the greater part fail to develop, and an uneven stand is the result. The stronger tubers succeed in growing, but the stem remains weak, the leaves are from the beginning considerably rolled and more or less colored. Few or no tubers are found in such hills, so that a complete crop failure results. Stem end browning of tubers is no longer considered a reliable evidence of leaf roll.

The true leaf roll is inheritable. The tubers from diseased plants produce diseased progeny as a general rule. This affords a means of distinguishing from genuine leaf roll those temporary conditions which give rise to a similar appearance of the plants. It is now quite generally admitted that the presence of fungous mycelium is not a character of the leaf roll. The leaf roll diseased plants in America have been free from fungous infection.

The leaf roll disease of potatoes first came into the public eye in Europe in 1905 in Westphalia. In 1907 a more general outbreak occurred in Germany and much alarm was expressed. Its occurrence is certain in Germany, Austria-Hungary, Switzerland, the Netherlands, Denmark, Norway and Sweden, as well as in the United States.

Two developments of leaf roll in this country have been studied. One in a collection of seedlings grown by the Bureau of Plant Industry, the other a destructive outbreak in eastern Colorado and western Nebraska during 1911 and 1912, which was the cause of immense losses, the shipments from one district falling from an expected 7000 cars to 200 cars.

The seedling potatoes showed every degree of variation in plant characters, and in addition many showed distinct evidence of the diseased condition herein described as leaf roll. It is noteworthy that in neither field was there any trace of Fusarium wilt, nor of Verticillium wilt, "black leg" or "mosaic," altho the latter three were common in adjoining fields. The evidence indicates that leaf roll and curly leaf are manifestations of physiological weakness and associated with decline or loss of vigor of the strain.

The hypotheses as to the cause of leaf roll are numerous and varied. It has been argued by one that leaf roll results from the use of unripe tubers for seed; by another, that it is due to the employment of matured tubers; while a third believes that seed from prematurely ripened plants is a cause of leaf roll.

Hiltner is the leading advocate of the theory that the immature seedstock gives an abnormal growth. He limits this to those potatoes which are prematurely ripened by drouth or other untoward circumstances. Hiltner further holds that leaf roll may be the result of an overconcentration of salts as thru excessive applications of fertilizer, of unbalanced composition and applied at the wrong time.

The first appearance of leaf roll in Germany was on the variety Magnum Bonum and was considered as an evidence of varietal deterioration. It seems certain, however, that leaf roll is not a result of "running out" of varieties thru old age, for many strains originated recently are affected. Its occurrence in seedlings has been observed by several workers. An interesting suggestion is put forward by Hedlung that leaf roll is a pathological adaptative mutation, and further, that since acquired characters are not inherited the leaf roll character must be latent in normal potatoes.

The introduction of new and more vigorous varieties affords a hopeful means of ultimately controlling the situation.

Under the name "curly-dwarf" there is to be differentiated from the leaf roll a peculiar disorder known in Germany as "Kräuselkrankheit." This is characterized by a dwarfed development of the potato plant, accompanied by a pronounced curling and wrinkling of the foliage, which has been compared with Scotch Kale and with Savoy cabbage. The stem and its branches, the leaf petioles and even the midribs and veins of the leaves all tend to be shortened in many cases to a very marked extent, particularly in the upper nodes of the plant, so that the foliage is thickly clustered. The diminished growth of the leaf veins, in proportion to the parenchyma, results in a bullate, wrinkled leaf, often strongly curled downward. There seems also to be a tendency to form more secondary branches than normal, and as these

remain short and with curly leaves, the compactness of the plants is more striking.

The color of the foliage in curly-dwarf is typically normal green. The tuber yield is greatly curtailed. Severe cases have no tubers. In others, a few small potatoes are formed. The hereditary nature of the trouble is attested by the German authorities and has been observed by the writer.

In the United States curly-dwarf plays a larger role in the deterioration of our potatoes than in Europe. It must be regarded as a physiological disorder, which crops out in previously healthy stocks, under conditions not yet known to us. Once developed, it is apparently not possible to restore the vigor of the affected hills.

Examination of a variety or seedling collection shows that there are all grades of the condition above described from pronounced types of curly-dwarf to those approaching normal vigor. It will furthermore be apparent that this is a difference inherent in the varieties or strain under observation.

Both leaf roll and curly dwarf develop suddenly from hitherto healthy stocks and both are transmitted by planting tubers from diseased plants. That whole districts should be affected as in Westphalia in 1907 and in Colorado in 1911 indicates a physiological deterioration due to environmental relations, unless a parasite should be demonstrated, which has not yet been done.

The climatic charts presented show that there is a great deficiency of moisture in Germany and Colorado in comparison with Chili. Is it possible that under these conditions varieties of potatoes may lose their vigor and undergo physiological changes comparable with those already noted for southern grown seed?

That the leaf roll disease is being brought under control in Germany by the use of healthy seed potatoes from outside the affected districts supports these hypotheses and lends still more strength to the argument for potato breeding for a higher degree of climatic adaptation.

Altho nothing like the present outbreak of leaf roll has occurred during the last forty years, an examination of old literature shows that about 1770 and in subsequent years there were epi-

demics of "leaf curl" and "Kräuselkrankheit" in England and Germany respectively, the description of which are much like the troubles of today.[2] Are our potato varieties passing thru another period of decline in vigor?

ZOOLOGY.—*Web-spinning fly larvae in Guatemalan caves.* O. F. Cook, Bureau of Plant Industry.

The limestone mountains of the Department of Alta Verapaz, in eastern Guatemala, abound in caves, most of them as yet quite unexplored. Ancient remains show that some of the caves were used for burial places in prehistoric times, which may account for the aversion of the present Indian population to entering this underground world. Two caves on the Trece Aguas coffee estate near Senahú were visited by the writer on March 30, 1906, to see whether they contained millipeds or other cave-dwelling arthropods.

In one of the caves, which was very dry, a few human teeth were found with small circular mounds of earth where ancient pottery vessels had crumbled, tho in some cases the rims remained. The other cave, which was entered by crawling thru a low narrow passage, partly filled with water, had also been used for burial purposes and one of the chambers showed a few rude designs traced in black, something after the manner of Mayan hieroglyphics. There were several large chambers, some of them with lofty roofs and extensive deposits of stalactites and stalagmites. The air was very damp owing to wet walls and dripping water. It was in one of the inner chambers of this cave, probably at least 100 yards from the entrance, that curious fringelike webs were noticed hanging from the roof. A sloping floor brought us up close to the webs, and the light of an acetylene lamp rendered the glistening threads very conspicuous against a background of complete darkness.

The general plan of these webs is entirely unlike that of any spider or other web-building arthropod of the upper world, and could be used only in caves or in very sheltered recesses of forests.

[2] Cf. Thos. Dickson, Memoirs Caledonian Hort. Soc., March 6, 1810.